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Technology transfer and its effect on innovation

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Abstract

This paper analyses the relationship of technology transfer and innovation in a Cournot duopoly framework, where technology transfer between the firms may occur after the innovation decision is taken by the high cost firm. The possibility of licensing via fixed-fee or royalty, encourages (discourages) innovation if the cost difference between the firms is high (low). Hence, it is shown that technology transfer and innovation are substitutes (complements) if the cost difference between the firms is low (high).

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1. Introduction

The relationship between R&D and technology transfer has been studied empirically by a fairly large number of contributions (See Deolalikar and Evenson 1989, Cohen and Levinthal 1989, Ferrantino 1992, and Hu et al. 2005). The relationship between technology transfer and R&D can either be that of complements or substitutes. If, R&D and technology transfer have independent and similar effects on a firms knowledge base and productivity, then it acts as substitutes. Hence, (foreign) technology transfer may crowd-out (domestic) R&D effort. It is generally argued that the transfer of technology from foreign can reduce indigenous R&D effort and therefore the Indian government restricted the purchase of foreign technology (See Deolalikar and Evenson 1989). Love and Roper (1999) found that for 1300 UK manufacturing plants, R&D and technology transfer are substitutes in the innovation process. Cohen and Levinthal (1989) however, argue that R&D not only involves innovation but also learning. Hence, the relation is complementary: if R&D enhances a firms productivity, then in turn it boosts the efficacy of technology transfer. Hu et al. (2005) shows that for China's large and medium-size enterprises, in house R&D significantly complements technology transfer - whether of domestic or foreign origin. The present paper attempts to model this relationship of technology transfer and R&D (innovation), in terms of cost asymmetry between the firms.

There have been some attempts to model technology transfer and cost reducing innovation simultaneously in a Cournot competitive market structure.[1] Gallini and Winter (1985) is the first work, to consider the interaction between royalty licensing opportunities and innovation incentives. It shows that in a Cournot duopoly framework royalty licensing encourages innovation when the firms' initial cost difference is low and discourages innovation when the cost difference is high. Mukherjee and Mukherjee (2013) and Chang et al. (2013) study this relationship, but consider symmetric cost for the firms in the pre-licensing stage. In Mukherjee and Mukherjee (2013) fixed-fee licensing decreases innovation, but a two-part tariff licensing contract increases innovation. Chang et al. (2013) argues that if the licensor firms R&D efficiency is high, the availability of licensing reduces the firms R&D incentive, which in turn lead to a lower social welfare level. Sen and Tauman (2007) and Fauli-Oller et al. (2013) however, compares the innovation incentives of the patentee internal to the firm vs an external patentee.

The present paper is developed in a Cournot duopoly framework of cost asymme-

[1] An inefficient firm can acquire a superior technology via licensing and thus reduce its costs of production i) if it buy the technology directly from the research labs/outside innovators (see Kamien and Tauman 1986, Katz and Shapiro 1985) or ii) buy it from the rival firm (see Shapiro 1985, Marjit 1990, Wang 1998 and 2002, Fauli-Oller and Sandonis 2002, Sen 2014, etc). A parallel strand of literature also deals with innovation in an oligopolistic framework (See Delbono and Denicolo 1991, and Reinganum 1983).

try[2], where the higher cost firm decides for innovation in the pre-licensing stage.[3] It is built on the assumption that the low cost firm is passive in regards to innovation, as the objective is to examine the effect of licensing opportunities on high cost firm's R&D incentives, even if it knows that it cannot outstrip the low cost firm in cost.[4] It incorporates technology transfer and cost reducing innovation simultaneously, where technology transfer between the firms may occur after the innovation decision is made by the high cost firm. Licensing can be either through payment of fixed-fee or per-unit royalty. Using Nash-bargaining the optimal volume of payments is also identified for these different forms of licensing contract[5]. In fixed-fee licensing, the technology is transferred if the cost difference between the firms is low. Contrarily, in royalty licensing whatever be the cost difference technology is always transferred. However, the two possible effects of innovation are: i) accessing the superior technology of the low cost firm if higher cost prohibits technology transfer and ii) affecting the pricing rule of technology transfer via higher bargaining power.

As far as the regulations on technology transfer agreements, especially of European Union[6], is concerned technology transfer agreements must strengthen the incentive for the initial research and development and spur incremental innovation. However, in this paper, it is shown that both for fixed-fee as well as for royalty licensing, allowing licensing (removing barriers) discourages innovation (research) if the cost difference is low. This result is in contrast to Gallini and Winter (1985), where in a duopoly the availability of royalty licensing encourages research when the firms' initial production technologies are close in costs and discourages research when initial costs are asymmetric. Therefore, in the present model technology transfer and R&D are substitutes if the cost difference is low, as in such case licensing reduces the incentives for innovation. However, the relation is complementary if the cost difference is high, as for higher difference in cost licensing (fixed-fee and royalty) encourages innovation. Moreover, in case of fixed-fee licensing, the high cost firm licenses in the technology only if R&D activities reduce its cost below a particular threshold. This idea therefore validates the complementary relation as pointed by Cohen and Levinthal (1989),

[2]In the literature on horizontal mergers (e.g. Farrell and Shapiro 1990) cost asymmetry and cost synergy also play an important role. Lahiro and Ono (2004) presents a series of theoretical studies of important issues in international trade premised on the assumption that firms have asymmetric costs.

[3]Fauli-Oller et al. (2013), Mukherjee and Mukherjee (2013) and Chang et al. (2013) consider symmetric cost for the firms in the pre-licensing stage, and therefore in their structure, licensing can takes place only when innovation activities are carried out. However, the present paper considers asymmetric cost structures such that even if innovation activities are not undertaken, then also technology may be transferred.

[4]As the objective is to study only the R&D incentives of the domestic firm, it can be assumed that the foreign firm (licensor) is passive in regards to innovation.

[5]See Kishimoto and Moto (2012) and Monerris and Vannetelbosch (2001) for a similar type of analysis. They do not however consider endogenous innovation.

[6]COMMISSION REGULATION (EU) No 316/2014 of 21 March 2014 on the application of Article 101(3) of the Treaty on the Functioning of the European Union to categories of technology transfer agreements.

that is as R&D enhances the firm's productivity (reduces cost), it paves the way for technology transfer.

The scheme of this paper is as follows. In section 2 and section 4 technology transfer via fixed-fee and royalty are discussed respectively. Section 3 and section 5 incorporate the incentives for innovation of the high-cost firm, under fixed-fee and royalty licensing respectively. The last section finally concludes.

2. Technology transfer via fixed-fee

Consider a Cournot duopoly market, where the firms are producing a homogeneous product. The market demand is given by $P = a - bQ$, where Q is the total industry output. The two firms, firm 1 and firm 2 produce output, Q_1 and Q_2, at constant unit production cost c_1 and c_2 respectively. Without any loss of generality, assume $c_1 > c_2 = 0$, and therefore call firm 2 as the low cost firm and firm 1 as the high cost firm. P is the market price; $a, b > 0$ are constants. Assume $c_1 < \bar{c_1} = \frac{a}{2}$. For $c_1 \geq \bar{c_1}$, firm 2 is the monopolist. The profit of firm i in the no-licensing stage is $\Pi_i(c_i, c_j) = \frac{(a-2c_i+c_j)^2}{9b}$ where $i, j = (1, 2)$ and $i \neq j$.

Licensing can take place from firm 2 to firm 1 via fixed-fee, which results in the reduction of firm 1's unit cost from c_1 to 0. It is assumed in the present model, that the firms are engaged in Nash-bargaining to determine the fixed-fee (f). This is in contrast to Wang (1998), where firm 2 licenses its superior technology to firm 1 by charging a maximum fixed-fee (since it enjoys the full bargaining power), such that firm 1 is indifferent between licensing and no-licensing. Moreover, as the objective of the paper is to study how the possibility of licensing affects innovation incentives, it is therefore meaningful to consider that firm 1 enjoys some bargaining power. As otherwise, licensing will not affect the innovation incentives of firm 1. The optimal value of f is solved by

$$\max_{f} \Big[\Pi_1(0,0) - f - \Pi_1(c_1,0)\Big]\Big[\Pi_2(0,0) + f - \Pi_2(0,c_1)\Big] \tag{1}$$

subject to the individual rationality constraints of firm 1 and firm 2 respectively: $\Pi_1(0,0) - f \geq \Pi_1(c_1,0)$ and $\Pi_2(0,0) + f \geq \Pi_2(0,c_1)$. These constraints are satisfied if $c_1 \leq \tilde{c_1} = \frac{2a}{5}$ (See Marjit 1990). This implies that if the cost difference between the firms is not too high, the transfer of technology will take place. $\Pi_1(0,0) - f$ and $\Pi_2(0,0) + f$ are the profits of firm 1 and firm 2 respectively after the technology is transferred. Solving equation "(1)", we get

$$f^*(c_1) = \frac{\Pi_2(0,c_1) - \Pi_1(c_1,0)}{2} = c_1(2a - c_1)/6b. \tag{2}$$

Proposition 1. *Transfer of technology from the low cost firm to the high cost firm via fixed-fee takes place if $c_1 \leq \tilde{c_1}$ and the optimal fixed-fee is $f^*(c_1) = c_1(2a - c_1)/6b$.*

The above proposition highlights two things. First, if $c_1 > \tilde{c_1}$, then by reducing c_1 below $\tilde{c_1}$ via innovation (in the pre-licensing stage) firm 1 can appropriate firm 2's technology. Second, if $c_1 \leq \tilde{c_1}$, it can also reduce the burden of fixed-fee by reducing its pre-licensing cost. The next section therefore takes care of innovation incentives of firm 1 for reducing its unit cost.

3. Incentives for innovation under fixed-fee licensing

As in Mukherjee and Pennings (2011) and Chang et al. (2013), the present section incorporates only firm 1's incentive to innovate for reducing its unit cost in the pre-licensing stage.[7] In Gallini and Winter (1985), where licensing is through per-unit royalty, both firms make decisions on research (innovation) for cost reduction in the ex-ante period and production takes place in the ex-post period. Moreover, in Gallini and Winter (1985), the higher cost firm (in pre-innovation stage) after innovation may turn out to be the lower cost firm (in post-innovation stage) and can sell its technology to its rival. Chang et al. (2013) also sets up a three-stage game in which only one of the firms undertakes a cost-reducing R&D and may license the developed technology to the others by means of a two-part tariff. *Contrarily the present paper allows innovation by firm 1, but restrict the possibility of turning out to be the lower cost firm in the post-innovation stage. Holding firm 2 inactive in regards to innovation is for observing firm 1's incentive to innovate, even if it knows that it cannot outstrip firm 2 in cost.*

Firm 1 invests an amount K (> 0) for R&D and the post-innovation cost of firm 1 (say c) follows a uniform distribution with density $g(c) = \frac{1}{c_1}$ in the interval $[0, c_1]$, where c_1 is the initial unit cost of firm 1 in the pre-innovation stage. Consider $c_1 \leq \tilde{c_1}$, and let $L(c_1) = \Pi_1(0,0) - f^*(c_1) = \frac{a^2}{9b} - \frac{c_1(2a-c_1)}{6b}$ be the profit (net) of firm 1 after technology transfer when innovation activities are not undertaken. Under fixed-fee licensing, for all $c_1 > \tilde{c_1}$, when the firm does not invest it gets $\Pi_1(c_1, 0)$, whether or not technology is transferable, as there is no mutually beneficial solution to the bargaining game. Thus the incentives to invest are stronger when technology is transferable because

$$\int_0^{\tilde{c_1}} L(c)g(c)dc + \int_{\tilde{c_1}}^{c_1} \Pi_1(c,0)g(c)dc - \Pi_1(c_1,0) > \int_0^{c_1} \Pi_1(c,0)g(c)dc - \Pi_1(c_1,0), \quad (3)$$

where the left hand side is $M(c_1)$ and the right hand side is $M_0(c_1)$. $M(c_1)$ is the *expected increase in profit due to innovation* when technology is transferable and $M_0(c_1)$ is the *expected increase in profit due to innovation* when technology is not transferable. The expected increase in profit due to innovation can be called as the

[7]It can be assumed that firm 2's unit cost is very low, and it does not innovate as undertaking innovation activities for further cost reduction is very costly. Moreover, if the objective is to analyse the R&D incentives of the domestic firm in the presence of licensing opportunities from any foreign firm, holding firm 2 passive in regards to R&D makes sense.

"innovation incentives".[8] On the other hand, for all $c_1 \leq \tilde{c_1}$, when firm 1 does not invest it gets $L(c_1)$, as technology is transferable. However, incentives to invest may not be stronger when technology is transferable, because for $c_1 \leq \tilde{c_1}$

$$\int_0^{c_1} L(c)g(c)dc - L(c_1) > \int_0^{c_1} \Pi_1(c,0)g(c)dc - \Pi_1(c_1,0) \tag{4}$$

is not always true, where the left hand side is $M(c_1)$ and the right hand side is $M_0(c_1)$.

From equations "(3)" and "(4)", we get

$$\begin{aligned} M(c_1) &= \frac{3ac_1 - 2c_1^2}{18b} \quad for \quad c_1 \leq \tilde{c_1} \\ &= \frac{a^3 z}{bc_1} + \frac{2ac_1}{9b} - \frac{8c_1^2}{27b} \quad for \quad c_1 > \tilde{c_1} \end{aligned} \tag{5}$$

where $z = 0.002963$ and

$$M_0(c_1) = \frac{2ac_1}{9b} - \frac{8c_1^2}{27b}. \tag{6}$$

To decide on whether it invests or not the firm compares $M(c_1)$ or $M_0(c_1)$ with K. *If technology is transferable, firm 1 innovates if $M(c_1) > K$. On the other hand, if technology is not transferable, firm 1 innovates if $M_0(c_1) > K$.* It will be interesting to compare the innovation incentives with and without the possibility of technology transfer. From "Appendix A", it follows that: i) $M(c_1) < M_0(c_1) \quad if \quad c_1 < \hat{c_1}$, ii)

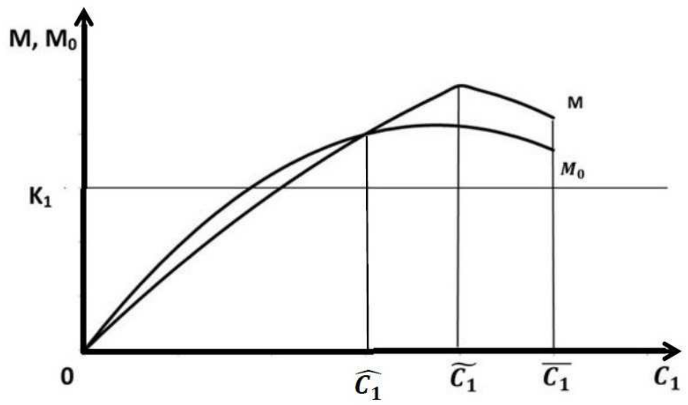

Figure 1: Innovation incentives: Fixed-fee

$M(c_1) = M_0(c_1) \quad if \quad c_1 = \hat{c_1}$ and iii) $M(c_1) > M_0(c_1) \quad if \quad c_1 > \hat{c_1}$; where $\hat{c_1} = \frac{3a}{8}$ and $\tilde{c_1} = \frac{2a}{5}$. Figure 1 also depicts the difference in the incentives for the two cases; i.e. when technology is transferable and when it is not. The two curves in Figure 1, M and M_0 denote respectively the innovation incentives (the expected returns from

[8] In the rest of the paper the term "innovation incentives" is used henceforth to signify the expected increase in profit due to innovation.

investment) when technology is transferable and when it is not. *The expected returns from investment are inverted U shaped (see Figure 1) not only when technology is transferable but also when it is not.* This suggests that incentives to invest (whether technology is transferable or not) are initially increasing and then decreasing in c_1. However, if $c_1 \leq \hat{c_1}(< \tilde{c_1})$, then only the incentives is more when technology is not transferable than without it. Therefore, the incentive for innovation is higher under the possibility of licensing if the cost difference is high or $c_1 > \hat{c_1}$.

For $c_1 \leq \tilde{c_1}$, as technology is transferred, whether firm 1 innovates or not (if technology is transferable), the motive behind innovation is to reduce the fixed-fee (f^*) by reducing its pre-transfer unit cost (as $\frac{df^*}{dc_1} > 0$, see equation "(2)") or to increase its reservation pay-off. If c_1 is close to 0, through innovation the unit cost can be reduced marginally. Therefore the gains from a reduction in fixed-fee ($M(c_1)$) is lower than $M_0(c_1)$. Firm 1 will not innovate if c_1 is very low such that (see Figure 1) $K = K_1 > M_0(c_1) > M(c_1)$. Similarly, if c_1 is marginally below $\tilde{c_1}$ the possibility of reducing the unit cost of firm 1 is much higher. The optimal fixed-fee can thereby be reduced significantly and therefore $M(c_1) > M_0(c_1)$. However, for $\tilde{c_1} < c_1 < \bar{c_1}$ the incentives to invest are stronger when technology is transferable ($M(c_1) > M_0$) as in that case firm 1 can have the access to the technology of firm 2 if the post-innovation unit cost (c) is below $\tilde{c_1}$.

Proposition 2. *The possibility of licensing via fixed-fee encourages innovation if the cost difference between the firms is high and discourages innovation if the cost difference is low.*

The above proposition signifies that technology transfer and R&D are substitutes if the cost difference between firms is low, as in such case licensing reduces the incentives for innovation. However, on the other hand the relation is complementary if the cost difference between firms is high, as for higher difference in cost licensing encourages innovation. In Gallini and Winter (1985), which deals only with royalty licensing, the availability of licensing encourages research when the firm's initial cost difference is small[9], while the present paper shows how the availability of licensing encourages innovation if the cost difference between the firms is high and discourages innovation if the cost difference is low. *It is discussed later in the present paper that this result holds even in the case of royalty licensing (Please see Proposition 5 and the discussion after it, where the difference in the results are explained).*

4. Royalty licensing

Technology licensing can also take place through a royalty (See Rostocker 1984, and Wang 1998). This section deals with a per-unit royalty (r) contract, as a tool of

[9]Though this result is true in Gallini and Winter (1985) in case of ex-ante licensing (licensing contract before innovation) as well as ex-post licensing (licensing contract after innovation), we will compare our result with the later case as the present model is of the genre of ex-post licensing.

technology transfer in the basic model outlined in section 2 [10]. The present section considers $c_1 \geq r \geq 0$ and introduces Nash-Bargaining for determining the royalty rate. The optimal value of r is solved by

$$\max_r \Big[\Pi_1^r(c_1) - \Pi_1(c_1, 0)\Big]\Big[\Pi_2^r(c_1) - \Pi_2(0, c_1)\Big] \tag{7}$$

subject to $c_1 \geq r \geq 0$, $\Pi_i^r(c_1) - \Pi_i(c_i, c_j) \geq 0$ [11]; $i, j = 1, 2$ $(i \neq j)$. $\Pi_i^r(c_1)$ and $\Pi_i(c_i, c_j)$ are the post-transfer and pre-transfer profit of firm i respectively; where $\Pi_1^r(c_1) = \frac{(a-2r)^2}{9b}$, $\Pi_1(c_1, 0) = \frac{(a-2c_1)^2}{9b}$, $\Pi_2^r(c_1) = \frac{(a+r)^2}{9b} + \frac{r(a-2r)}{3b}$ and $\Pi_2(0, c_1) = \frac{(a+c_1)^2}{9b}$. Solving equation "(7)", we get the optimal $r = r^*(c_1) = \frac{a}{2} - \frac{\sqrt{100a^2-280ac_1+160c_1^2}}{20}$. Under this contract the technology is always transferred and the profits of firm 1 and firm 2 after licensing are

$$\Pi_1^r(c_1) = \frac{a^2}{9b} + \frac{8c_1^2 - 14ac_1}{45b} \quad and \quad \Pi_2^r(c_1) = \frac{a^2}{9b} + \frac{7ac_1 - 4c_1^2}{18b} \tag{8}$$

respectively.

Proposition 3. *Under royalty licensing, technology is always transferred and the royalty rate is* $r^*(c_1) = \frac{a}{2} - \frac{\sqrt{100a^2-280ac_1+160c_1^2}}{20}$.

5. Incentives for innovation under royalty licensing

Let us analyse firm 1's incentive to innovate for reducing its unit cost in case of royalty licensing. The cost after innovation (c) is assumed to follow a uniform distribution in $[0, c_1]$ as before. As in fixed-fee licensing, here also innovation incentives before the transfer of technology arises only for increasing the reservation pay-off or for reducing the per unit royalty rates for buying the technology. The *expected increase in profit due to innovation* when technology is transferable is

$$H(c_1) = \int_0^{c_1} \Pi_1^r(c)g(c)dc - \Pi_1^r(c_1) = \frac{21ac_1 - 16c_1^2}{135b}. \tag{9}$$

This implies that firm 1 will innovate if $H(c_1) > K$. Let us compare the *innovation incentives* with and without the possibility to licensing. $H(c_1)$ is the expected increase in profit due to innovation or *innovation incentives* when technology is transferable via royalty. However, $M_0(c_1)$ (defined in Section 3) is the *innovation incentives* when technology is not transferable. Figure 2 shows that for a lower unit cost, if the government allows licensing, incentives for innovation will decrease; while for higher unit cost, allowing licensing will increase incentives for innovation.

[10] We desist from discussing the two-part tariff contract, as because in this set-up the fixed-fee then will be zero and $r > 0$.

[11] This is the individual rationality condition for firm i.

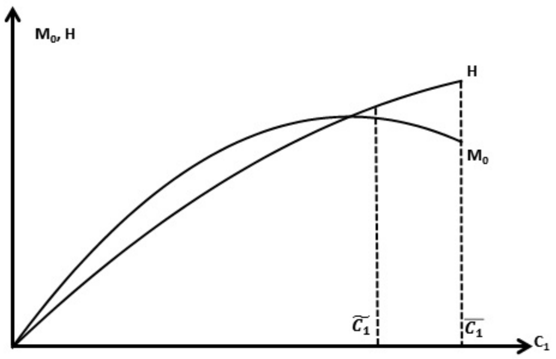

Figure 2: Innovation incentives: Royalty

Proposition 4. *The possibility of licensing via royalty encourages innovation if the cost difference between the firms is high and discourages innovation if the cost difference is low.*

This implies that, as in fixed-fee licensing, here also technology transfer and R&D are substitutes if the cost difference is low, as in such case licensing reduces the incentives for innovation. However, the relation is complementary if the cost difference is high, as for higher difference in cost licensing encourages innovation. As technology is always transferred, whether firm 1 innovates or not (if technology is transferable), the incentives for innovation is to reduce the royalty rate (r^*) by reducing its pre-transfer unit cost (as $\frac{dr^*}{dc_1} > 0$). If c_1 is close to 0, through innovation the unit cost can be reduced marginally, hence the gains from the reduction in royalty rates ($H(c_1)$) is lower than $M_0(c_1)$. On the other hand, if c_1 is marginally below $\bar{c_1}$, the possibility of reducing the cost is much higher, r^* can be reduced significantly and hence $H(c_1) > M_0(c_1)$.

The incentive for innovation irrespective of licensing scheme (both in fixed-fee and in royalty licensing) is more without the possibility of technology transfer if the initial cost (cost difference) is low. On the other hand, it is less without any barriers to technology transfer if the initial cost (cost difference) is high. This proposition is just in contrast to Gallini and Winter (1985), where royalty licensing encourages research if the cost difference is low. This is because, in the present model fixed-fee as well as royalty licensing encourages research if the cost difference is high. In Gallini and Winter (1985) "incentive for licensing leads to further research when research would stop without licensing and when variation in costs is small, because a firm considering research foresees the additional profits from further research. When cost differences are large, however, the high-cost firm, which is the one engaging in research, faces relatively little chance of collecting royalties, and is therefore not greatly encouraged by the possibility of ex post licensing". The difference in the result clearly arises, as in the present model irrespective of the cost difference in the pre-licensing stage, the high-cost firm (firm 1) knows that in the post innovation stage, it cannot license its technology to the low-cost firm (firm 2, who does not innovate as its unit cost is very less, say zero). This is because, after licensing firm 1 cannot reduce its cost below the unit cost of firm 2. The incentives for innovation in the present model is only for reducing the royalty rate/fixed-fee (always in case royalty licensing and if $c_1 \leq \tilde{c_1}$ in case of fixed-fee licensing) as technology is always licensed in the absence of innovation. Contrarily, in case of Gallini and Winter (1985) pre-licensing and post-licensing profit of the high-cost firm (after innovation), are same as the low-cost firm enjoys the full bargaining power and charges the royalty rates accordingly. Therefore, in their framework licensing affects a firm's (say firm x) innovation incentives, if it can reduce its cost below that of the other firm, such that it licenses its technology to the other firm and gains some revenue from it. Otherwise, firm x will buy the technology from the other firm, which will not give firm x any benefits. In case of royalty licensing also if full bargaining power is bestowed on firm 2 as in Gallini and Winter (1985) and if it is assumed that firm 2 is always the lower cost firm (if or if not firm 1 innovates), innovation incentives will be unaffected by licensing opportunities as $H(c_1) = M_0(c_1)$. (This is also true for fixed-fee licensing as discussed before.) This implies that whatever be the form of licensing contracts, fixed-fee or per-unit royalty, innovation incentives is unaffected by licensing opportunities if full bargaining power is enjoyed by firm 2.

However, if $\tilde{c_1} < c_1 < \bar{c_1}$, in case of fixed-fee licensing the incentives for innovation are for accessing the technology of firm 2, if after innovation technology is transferred, and for larger market share if after innovation licensing fails. In this context also if it is assumed that firm 2 is always the lower cost firm (if or if not firm 1 innovates) and enjoys the full bargaining power, innovation incentives will be unaffected by licensing opportunities as $M(c_1) = M_0(c_1)$.[12] Therefore, the main reason for the difference in the results in the present model are: i) firm 1's unit cost is greater than firm 2's unit cost even in the post innovation stage and firm 2 does not innovate and ii) firm 2 not enjoying full bargaining power, such that the royalty/fixed-fee is charged in such a way for which the licensee's pre-licensing and post-licensing profit are same.

6. Conclusion

A number of empirical studies exhibit that technology transfer and R&D (innovation activities) can be either complements or substitutes. The present paper models this relation of technology transfer and R&D, and explains it in terms of cost asymmetry between the firms. It analyses how incentive to innovate is affected by the licensing scheme, where technology transfer between the firms may occur after the innovation decision is made by the inefficient firm. Irrespective of licensing scheme, it is shown that the incentive to innovate is more with barriers to technology transfer than without it if the cost difference is low. On the other, hand when the cost difference is high, allowing licensing gives more incentive to innovate. Hence, technology

[12] This is because as in Wang (1998), if firm 2 sets the fixed-fee such that firm 1 is indifferent between licensing and no-licensing. Then, $L(c_1) = \Pi_1(c_1, 0)$ for $c_1 \leq \tilde{c_1}$ (implying that firm 1 is indifferent between licensing or not), and from equations "(3)" and "(4)" it can be said that $M(c_1) = M_0(c_1)$ for all $c_1 < \bar{c_1}$.

transfer and innovation are substitutes (complements) if the cost difference between the firms is low (high).

In the present era of globalization and integration technology transfer between firms has become more common than ever (See Vishwasrao 2007). The present model can be used to envisage a role of the government in the developing countries. Suppose the low cost firm and the high cost firm are located in developed and developing respectively, and compete in quantities in the market of the developing country. The paper then predicts, once the developing country allows licensing the incentives to innovate of the inefficient firm may either increase or decrease. This depends on the technology difference with the efficient firm. The government of a developing country may give incentive to the home (inefficient) firm in the form of subsidy for innovation if sufficiently high initial cost prohibits technology transfer.[13]

Appendix A.

From equation "(6)" we have $M_0(c_1) = \frac{2ac_1}{9b} - \frac{8c_1^2}{27b}$ for $0 < c_1 < \bar{c_1}$. For $c_1 \in (0, \tilde{c_1}]$, $M(c_1) - M_0(c_1) = \frac{10c_1^2 - 3ac_1}{54b}$, as $M(c_1) = \frac{3ac_1 - 2c_1^2}{18b}$. Initially $M(c_1) - M_0(c_1) < 0$ for $c_1 < \frac{3a}{10} = \hat{c_1}$, and $M - M_0 = 0$ at $c_1 = \frac{3a}{10}$. Finally for $\tilde{c_1} \geq c_1 > \hat{c_1}$, $M(c_1) > M_0(c_1)$. For $c_1 > \tilde{c_1}$, $M(c_1) = \frac{a^3 z}{bc_1} + \frac{2ac_1}{9b} - \frac{8c_1^2}{27b}$ where $z = 0.002963$; and $M(c_1) - M_0(c_1) = \frac{a^3 z}{bc_1} > 0$. Therefore $M(c_1) < M_0(c_1) \;\; if \;\; c_1 < \hat{c_1}, M(c_1) = M_0(c_1) \;\; if \;\; c_1 = \hat{c_1}$ and $M(c_1) > M_0(c_1) \;\; if \;\; c_1 > \hat{c_1}$.

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[13] It can also be shown in the present model, that if the low cost firm is a foreign firm and the high cost firm is the domestic firm and both compete in the home market, then after innovation the welfare (sum of consumer surplus and the domestic firm's profit) of the domestic economy always increases.

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